Hyperspectral Monitoring of Invasive, Non-Native Plant Species With EO-1 Hyperion Imagery

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This study tested the ability of hyperspectral imagery from the Hyperion sensor onboard the Earth Observing-1 (EO-1) satellite to detect and quantify the abundance of *Tamarix ramosissima* (tamarisk, saltcedar), a problematic invasive species in the United States. *T. ramosissima* is a wispy, needleleaf, deciduous tree species. Infestation of riparian zones by such non-native plants can displace native vegetation, impede water flow, increase sedimentation, use excessive water, and increase soil salinity, as well as decrease habitat for wildlife. Statistical classification of tamarisk in Hyperion imagery was compared to results using the Enhanced Thematic Mapper (ETM+) sensor on Landsat 7. The ability of Hyperion to estimate the cover fraction of tamarisk with discriminant functions and linear mixture models was compared to results from the AVIRIS sensor.

Two study areas in western Nevada were selected where infestations of *T. ramosissima* of significant local concern. One site was on the Walker River Paiute Tribe Reservation south of Schurz, Nevada (38.90 N, 118.78 W), and the other was the Stillwater National Wildlife Refuge (39.54 N, 118.49 W). Tamarisk infestations at the Walker river site occurred in large patches along and around the riparian zone, representing a mosaic of fire and flood disturbance history. Infestation at the Stillwater site was concentrated in narrow bands along canals and at high water margins. Field data collection was performed in the summer of 2000 and 2001, after the herbaceous layer had senesced. Canopy cover measurements were made using 30 x 30-meter quadrats that were subjectively located to represent a range of field conditions in both study areas (e.g. tamarisk density, age of stand, mixtures with other green vegetation). Canopy cover was measured by line intercept, and proportions of other green ground cover were calculated by point intercept on meter intervals along the transects. Field spectra were acquired during the EO-1 data acquisitions using a FieldSpec Full Range Pro (Analytical Spectral Devices) spectrometer.

Low-altitude AVIRIS data was collected over the Lower Walker River study area on July 21, 2000, with a ground resolution of 3.7 meters. Imagery was converted to reflectance using ATREM, followed by a flat-field correction that adjusted band gains to match field-measured values in a large, bare calibration area. AVIRIS data were resampled to match the Hyperion bands used in this study. Discriminant function analysis (DFA), mixture-tuned matched filtering, and linear mixture modeling were used to assess the ability to map percent canopy cover of tamarisk. The DFA using all 174 resampled spectral bands provided the best results, with a respectable r^2 of 0.79 and the least amount of average confusion with other green vegetation. The top left of Figure 1 shows the selected wavelengths and their weightings from a stepwise DFA superimposed on the average reflectance of tamarisk from the Walker River study area. The fit of the resulting linear combination against field measured tamarisk cover is shown at the bottom left. Some erroneous tamarisk estimates are made in areas of other green vegetation, but the majority of the estimates correctly indicate 0% tamarisk (bottom center). The right side of the figure shows the results of the DFA regression estimates. Mixture modeling using MNF transformed data and the average spectral reflectance of subjectively chosen vegetation classes as endmembers performed almost as well. The mixture-tuned matched filtering method performed quite poorly.

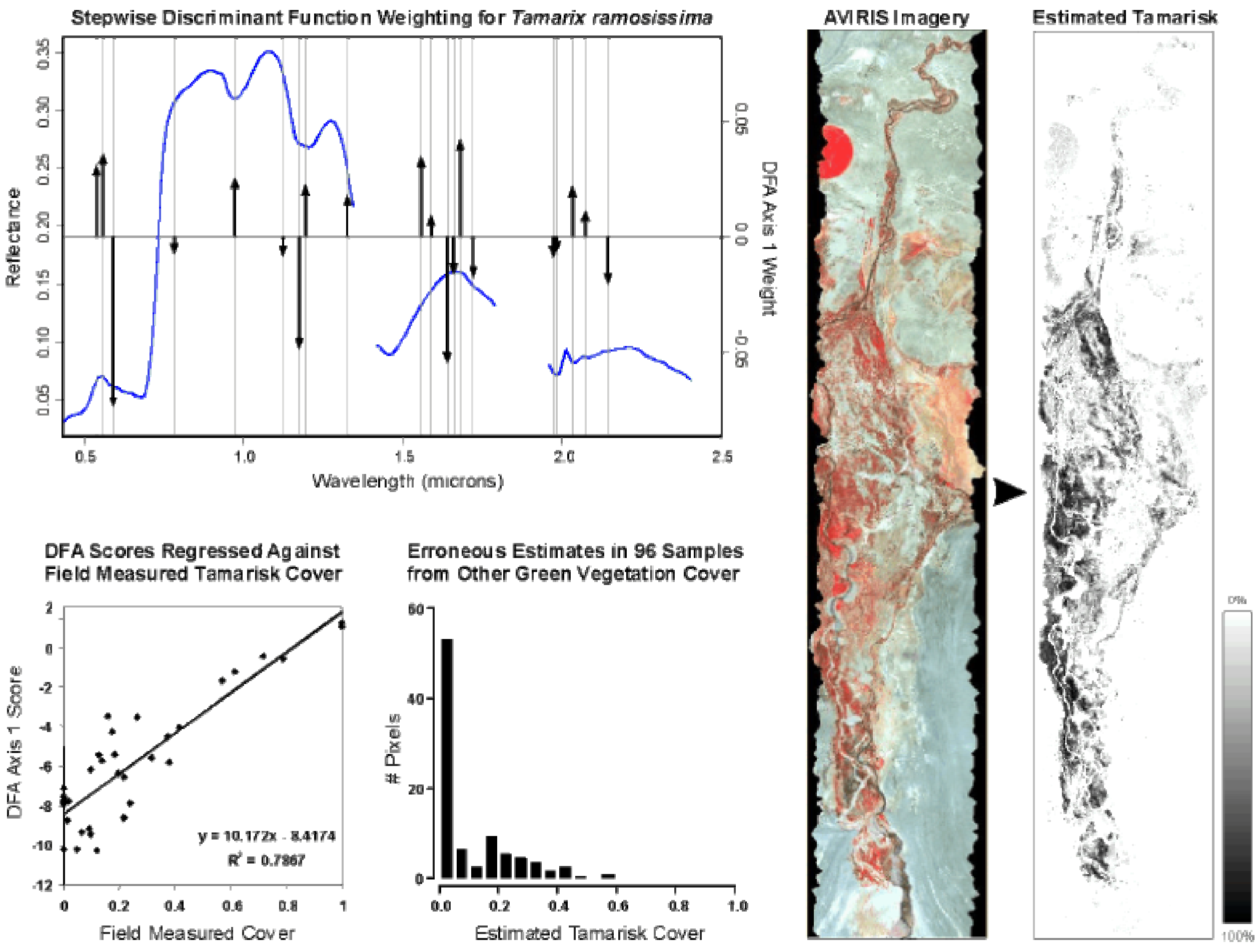

Figure 1. Discriminant function analysis on hyperspectral AVIRIS imagery.

The Hyperion imagery used in this study was collected on August 15, 2001. SWIR channels for Hyperion displayed strong along-track striping. Precise correction of this artifact was difficult since Hyperion is a push-broom detector, with no repeating ground coverage between detectors. Attempts to destripe by normalizing column means or fitting differences between adjacent columns did not provide adequate results, so destriping was not used. Hyperion data were converted to reflectance using an empirical line correction with invariant bright and dark targets identified in the AVIRIS imagery. Landsat 7 ETM+ imagery of the two areas was acquired contemporaneously with Hyperion.

Tamarisk patches in Hyperion and ETM+ data were classified using both unsupervised and supervised methods. For ETM+, classification accuracy in the Walker site was consistently higher than for Stillwater. This was expected since much of the infestation in the Stillwater site was in the form of linear strands along canals and lake margins that were at or below the 30-meter pixel size. Hyperion data provided higher overall classification accuracy than ETM (Figure 2). The best result for Hyperion at the Walker River site was 85.5% using maximum likelihood with the minimum noise fraction (MNF) transformation as input. This compares with 78% for maximum likelihood classification of ETM+. The best Hyperion result at Stillwater was 82.5% using the ISODATA classifier with MNF bands. The best ETM+ result at Stillwater was 66.5% using the maximum likelihood classifier. Interestingly, with some classification techniques the Hyperion results for Stillwater were as good or better than Walker River, despite the increased problem with mixed pixels. The spectral angle mapper classification technique for hyperspectral data was tested, but consistently performed much worse than the other methods. The only consistent advantage among the various classification methods across the two study sites was the utility of the MNF transformation in improving results by reducing image noise.

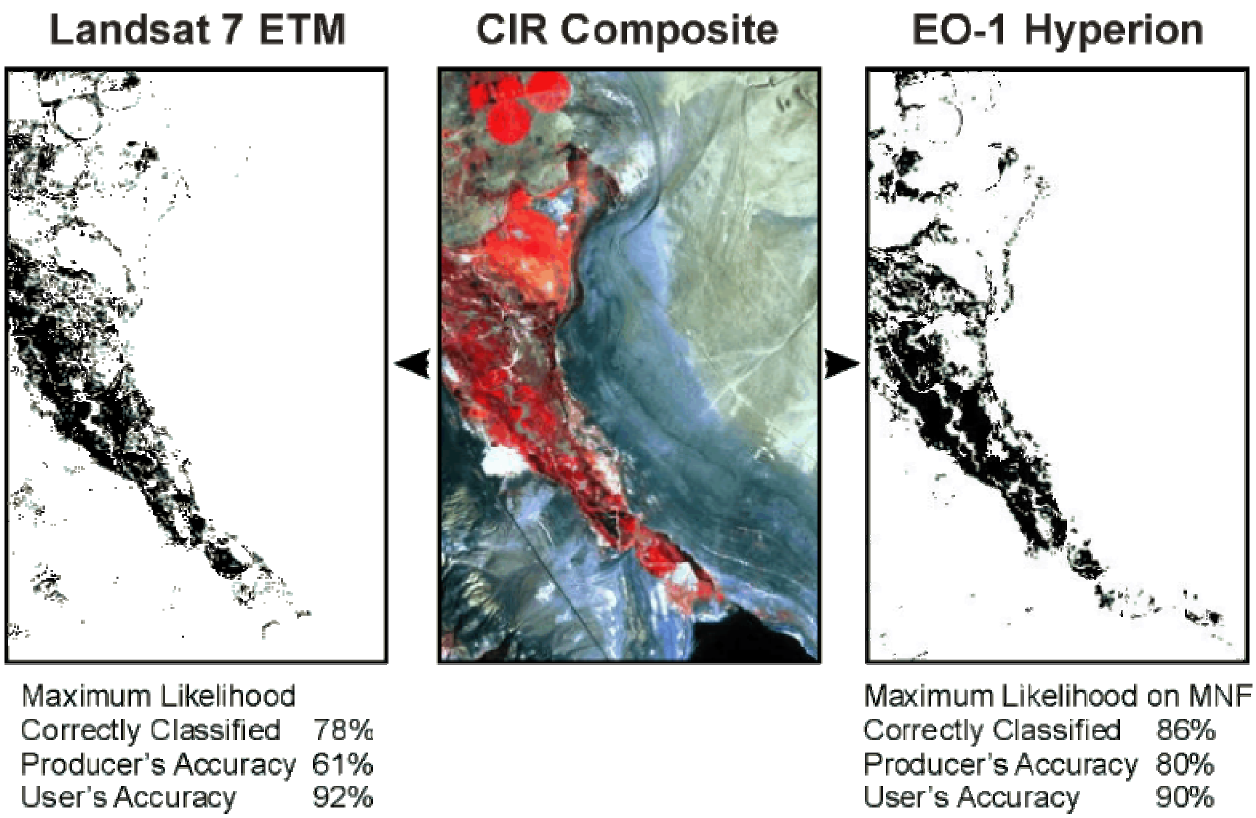

Figure 2. Classification accuracy improves with Hyperion.

Based on experience with low-altitude AVIRIS data over the Walker River, three different methods were tested for generating continuous estimates of tamarisk cover. First, the DFA weighting function that was developed with the AVIRIS data was applied directly to the Hyperion data. Second, a new DFA was performed using the Hyperion data as input. Third, a linear mixture model was tested using the MNF transformation with endmembers derived from the Hyperion imagery. Results for the AVIRIS-based DFA transformation performed the worst, being strongly affected by striping in the Hyperion imagery ($r^2 = 0.23$). When performing a new DFA using the Hyperion imagery, the weighting function changed noticeably, most likely due to the avoidance of noisy spectral bands. The results for the Hyperion-based DFA were better, but were still sensitive to striping ($r^2 = 0.40$) (Figure 3). Linear mixture model with the MNF transformation provided the best sensitivity to tamarisk cover ($r^2 = 0.56$). Selective use of MNF bands with high eigenvalues substantially reduced the propagation of striping and noise into the estimates of tamarisk cover. However, there was substantial confusion between tamarisk and other vegetation types with the mixture modeling approach.

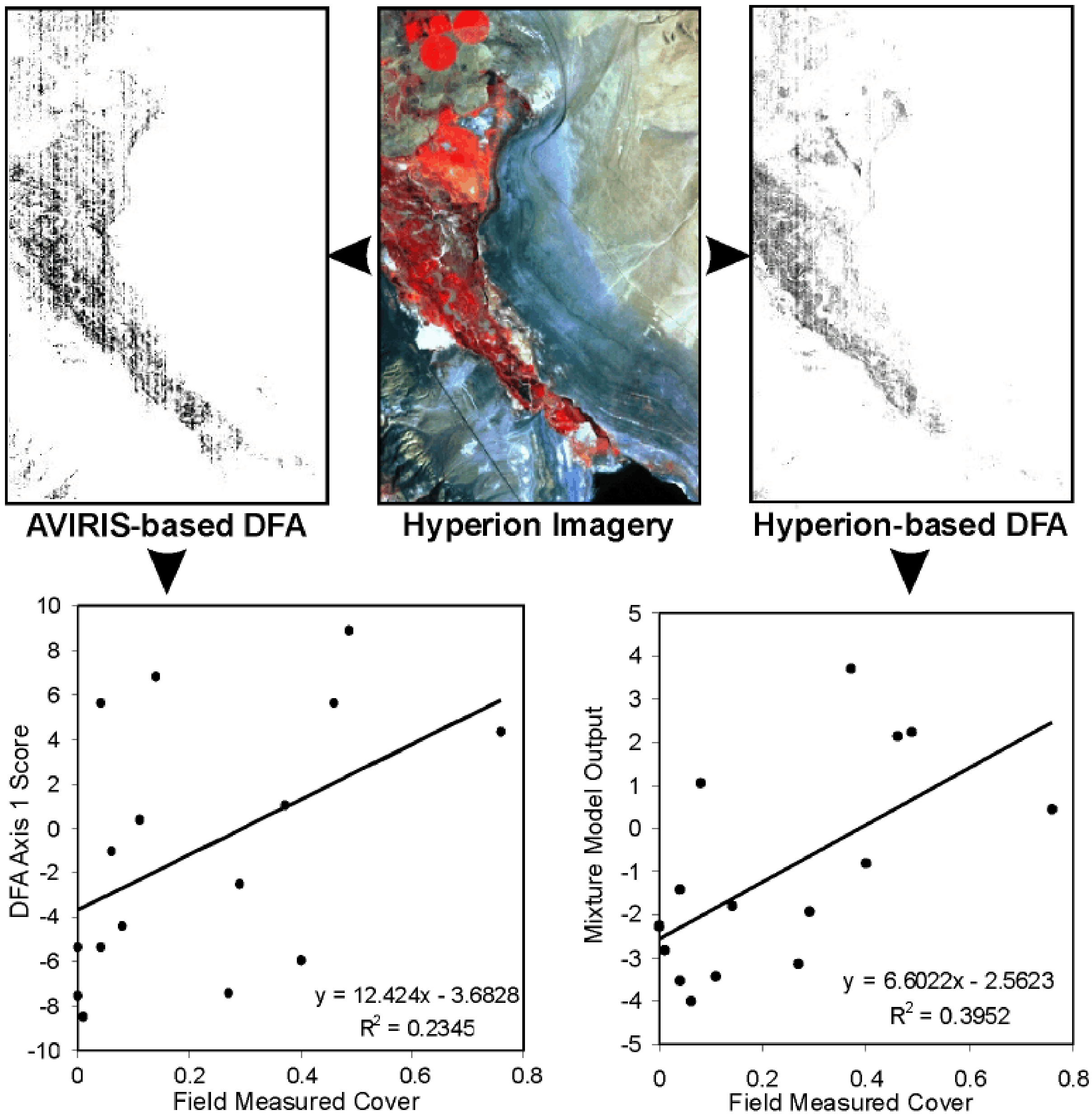

Figure 3. Estimating tamarisk cover from Hyperion is less successful than for AVIRIS.